WHAT IS CLAIMED IS:

Fig 14-15

1. An exchange coupling film comprising an antiferromagnetic layer and a ferromagnetic layer, which are formed in contact with each other so that the magnetization direction of the ferromagnetic layer is pinned in a predetermined direction by an exchange coupling magnetic field produced at the interface between both layers, wherein the antiferromagnetic layer is made of an antiferromagnetic material comprising an element X (at least one element selected from Pt, Pd, Ir, Rh, Ru, and Os) and Mn; and

in a section of the exchange coupling film in parallel with the thickness direction thereof, the crystal grain boundaries formed in the antiferromagnetic layer and the crystal grain boundaries formed in the ferromagnetic layer are discontinuous in at least a portion of the interface.

2. An exchange coupling magnetic film according to Claim 1, wherein in the antiferromagnetic layer and the ferromagnetic layer, equivalent crystal planes represented by a {111} plane are preferentially oriented in parallel with the interface.

3. An exchange coupling film according to Claim 1, comprising the antiferromagnetic layer and the ferromagnetic layer which are laminated in this order from the bottom, and a seed layer formed below the ferromagnetic layer and having

a crystal structure mainly composed of a face-centered cubic crystal in which equivalent crystal planes represented by the {111} plane are preferentially oriented in parallel with the interface.

4. An exchange coupling film according to Claim 3, wherein the seed layer is made of a NiFe alloy, Ni, a Ni-Fe-Y alloy (wherein Y is at least one element selected from Cr, Rh, Ta, Hf, Nb, Zr, and Ti), or a Ni-Y alloy.

5. An exchange coupling film according to Claim 4, wherein the seed layer is represented by the composition formula $(Ni_{1-x}Fe_x)_{1-y}Y_y$ (x and y are atomic ratios) wherein the atomic ratio x is 0 to 0.3, and the atomic ratio y is 0 to 0.5.

6. An exchange coupling film according to Claim 3, wherein the seed layer is nonmagnetic at normal temperature.

7. An exchange coupling film according to Claim 3, further comprising an underlying layer formed below the seed layer and comprising at least one element selected from Ta, Hf, Nb, Zr, Ti, Mo and W.

8. An exchange coupling film according to Claim 3, wherein at least a portion of the interface between the antiferromagnetic layer and the seed layer is in an

incoherent state.

9. An exchange coupling film according to Claim 1, wherein the antiferromagnetic layer is made of a X-Mn-X' alloy (wherein X' represents at least one element selected from Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the rare earth elements).

10. An exchange coupling film according to Claim 9, wherein the X-Mn-X' alloy is an interstitial solid solution in which the element X' enters the interstices between space lattices composed of the element X and Mn, or a substitution solid solution in which the lattice points of crystal lattices composed of the element X and Mn are partially substituted by the element X'.

11. An exchange coupling film according to Claim 1, wherein the composition ratio of the element X or elements (X + X') is 45 at% to 60 at%.

12. An exchange coupling film according to Claim 1, wherein at least a portion of the interface between the antiferromagnetic layer and the ferromagnetic layer is incoherent.

13. A magnetoresistive element comprising an

antiferromagnetic layer, a pinned magnetic layer formed in contact with the antiferromagnetic layer so that the magnetization direction is pinned by an exchange coupling magnetic field with the antiferromagnetic layer, a free magnetic layer formed on the pinned magnetic layer with a nonmagnetic intermediate layer provided therebetween, and a bias layer for orienting the magnetization direction of the free magnetic layer in a direction crossing the magnetization direction of the pinned magnetic layer, wherein the antiferromagnetic layer and the pinned magnetic layer formed in contact with the antiferromagnetic layer comprise an exchange coupling film according to Claim 1.

14. A magnetoresistive element comprising an antiferromagnetic layer, a pinned magnetic layer formed in contact with the antiferromagnetic layer so that the magnetization direction is pinned by an exchange coupling magnetic field with the antiferromagnetic layer, a free magnetic layer formed on the pinned magnetic layer with a nonmagnetic intermediate layer provided therebetween, and antiferromagnetic exchange bias layers formed on or below the free magnetic layer with a space corresponding to a track width Tw, wherein the exchange bias layers and the free magnetic layer comprise an exchange coupling film according to Claim 1, and magnetization of the free magnetic layer is pinned in a predetermined direction.

15. A magnetoresistive element comprising nonmagnetic layers laminated on and below a free magnetic layer, pinned magnetic layers located on one of the nonmagnetic intermediate layers and below the other nonmagnetic intermediate layer, antiferromagnetic layers located on one of the pinned magnetic layers and below the other pinned magnetic layer, for pinning the magnetization direction of each of the pinned magnetic layers in a predetermined direction by an exchange coupling magnetic field, and a bias layer for orienting the magnetization direction of the free magnetic layer in a direction crossing the magnetization direction of the pinned magnetic layers, wherein the antiferromagnetic layers and the pinned magnetic layers respectively formed in contact with the antiferromagnetic layers comprise an exchange coupling film according to Claim 1.

16. A magnetoresistive element comprising a magnetoresistive layer and a soft magnetic layer which are laminated with a nonmagnetic layer provided therebetween, and antiferromagnetic layers formed on or below the magnetoresistive layer with a space therebetween corresponding to a track width Tw, wherein the antiferromagnetic layers and the magnetoresistive layer comprise an exchange coupling film according to Claim 1.

17. An exchange coupling film comprising an

antiferromagnetic layer and a ferromagnetic layer, which are formed in contact with each other so that the magnetization direction of the ferromagnetic layer is pinned in a predetermined direction by an exchange coupling magnetic field produced at the interface between both layers;

wherein an equivalent crystal plane represented by a {111} plane of the antiferromagnetic layer is preferentially oriented in parallel to the interface; and

a twin crystal is formed in at least a portion of the antiferromagnetic layer so that the twin boundaries of the twin crystal are nonparallel to the interface.

18. An exchange coupling film according to Claim 17, wherein the inner angle between each of the twin boundaries and the interface is 68° to 76°.

19. An exchange coupling magnetic film according to Claim 17, wherein in the antiferromagnetic layer, the equivalent crystal plane represented by the {111} plane is preferentially oriented in parallel with the interface.

20. An exchange coupling magnetic film according to Claim 17, wherein the antiferromagnetic layer is made of an antiferromagnetic material comprising an element X (at least one element selected from Pt, Pd, Ir, Rh, Ru, and Os) and Mn.

21. An exchange coupling film according to Claim 17,

comprising the antiferromagnetic layer and the ferromagnetic layer which are laminated in this order from the bottom, and a seed layer formed below the ferromagnetic layer and having a crystal structure mainly composed of a face-centered cubic crystal in which an equivalent crystal plane represented by the {111} plane is preferentially oriented in parallel with the interface.

22. An exchange coupling film according to Claim 21, wherein the seed layer is made of a NiFe alloy, Ni, a Ni-Fe-Y alloy (wherein Y is at least one element selected from Cr, Rh, Ta, Hf, Nb, Zr, and Ti), or a Ni-Y alloy.

23. An exchange coupling film according to Claim 22, wherein the seed layer is represented by the composition formula $(Ni_{1-x}Fe_x)_{1-y}Y_y$ (x and y are atomic ratios) wherein the atomic ratio x is 0 to 0.3, and the atomic ratio y is 0 to 0.5.

24. An exchange coupling film according to Claim 21, wherein the seed layer is nonmagnetic at normal temperature.

25. An exchange coupling film according to Claim 21, further comprising an underlying layer formed below the seed layer and comprising at least one element selected from Ta, Hf, Nb, Zr, Ti, Mo and W.

26. An exchange coupling film according to Claim 21, wherein at least a portion of the interface between the antiferromagnetic layer and the seed layer is in an incoherent state.

27. An exchange coupling film according to Claim 17, wherein the antiferromagnetic layer is made of a X-Mn-X' alloy (wherein X' represents at least one element selected from Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the rare earth elements).

28. An exchange coupling film according to Claim 27, wherein the X-Mn-X' alloy is an interstitial solid solution in which the element X' enters the interstices between space lattices composed of the element X and Mn, or a substitution solid solution in which the lattice points of crystal lattices composed of the element X and Mn are partially substituted by the element X'.

29. An exchange coupling film according to Claim 17, wherein the composition ratio of the element X or elements (X + X') is 45 at% to 60 at%.

30. An exchange coupling film according to Claim 17, wherein at least a portion of the interface between the antiferromagnetic layer and the ferromagnetic layer is

incoherent.

31. A magnetoresistive element comprising an antiferromagnetic layer, a pinned magnetic layer formed in contact with the antiferromagnetic layer so that the magnetization direction is pinned by an exchange coupling magnetic field with the antiferromagnetic layer, a free magnetic layer formed on the pinned magnetic layer with a nonmagnetic intermediate layer provided therebetween, and a bias layer for orienting the magnetization direction of the free magnetic layer in a direction crossing the magnetization direction of the pinned magnetic layer, wherein the antiferromagnetic layer and the pinned magnetic layer formed in contact with the antiferromagnetic layer comprise an exchange coupling film according to Claim 17.

32. A magnetoresistive element comprising an antiferromagnetic layer, a pinned magnetic layer formed in contact with the antiferromagnetic layer so that the magnetization direction is pinned by an exchange coupling magnetic field with the antiferromagnetic layer, a free magnetic layer formed on the pinned magnetic layer with a nonmagnetic intermediate layer provided therebetween, and antiferromagnetic exchange bias layers formed on or below the free magnetic layer with a space corresponding to a track width Tw, wherein the exchange bias layers and the free magnetic layer comprise an exchange coupling film

according to Claim 17, and magnetization of the free magnetic layer is pinned in a predetermined direction.

33. A magnetoresistive element comprising nonmagnetic layers laminated on and below a free magnetic layer, pinned magnetic layers located on one of the nonmagnetic intermediate layers and below the other nonmagnetic intermediate layer, antiferromagnetic layers located on one of the pinned magnetic layers and below the other pinned magnetic layer, for pinning the magnetization direction of each of the pinned magnetic layers in a predetermined direction by an exchange coupling magnetic field, and a bias layer for orienting the magnetization direction of the free magnetic layer in a direction crossing the magnetization direction of the pinned magnetic layers, wherein the antiferromagnetic layers and the pinned magnetic layers respectively formed in contact with the antiferromagnetic layers comprise an exchange coupling film according to Claim 17.

34. A magnetoresistive element comprising a magnetoresistive layer and a soft magnetic layer which are laminated with a nonmagnetic layer provided therebetween, and antiferromagnetic layers formed on or below the magnetoresistive layer with a space therebetween corresponding to a track width Tw, wherein the antiferromagnetic layers and the magnetoresistive layer

comprise an exchange coupling film according to Claim 17.